DOES EXPOSURE TO DIESEL EMISSIONS INCREASE CANCER MORTALITY RISK FOR PHILADELPHIA FIREFIGHTERS?

EXECUTIVE DEVELOPMENT

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ABSTRACT

Starting in 1969 the Philadelphia Fire Department began the conversion of their fleet of fire trucks from gasoline to diesel power. No fire station utilized diesel emission control systems. In 1969 several fire stations dated back to the first part of the century, and because of their design, diesel emissions migrated easily from the apparatus floor into the offices and living spaces. As a result firefighters who worked in fire station operating diesel fire trucks were exposed to diesel emissions. Diesel emissions contain toxic and carcinogenic products of combustion. Firefighters that are exposed to diesel emissions in the fire station may face an increased risk of cancer mortality. For this study we assembled work histories for 6,477 Philadelphia firefighters, collected 1,222 death certificates, compiled a history of apparatus assignment back to the last century and located data on Philadelphia fire company responses 1935-1986. Using these data; we considered lifetime fire station exposure to diesel emissions as a risk factor; calculated person-years in each exposure category (zero-exposed, low-exposed, medium exposed and high exposed) stratified across age and calendar years; then compared cancer mortality risk rates of the four groups to test our hypothesis. Although we found elevated cancer risk rates for the exposed groups, none were statistically significant. Diesel emission exposure remains a serious health risk. Fire Departments should take steps to eliminate firefighters exposure to diesel emissions.

TABLE OF CONTENTS

ABSTRACT...i

TABLE OF CONTENTS..................................iii

INTRODUCTION...1

BACKGROUND AND SIGNIFICANCE..........................3

LITERATURE REVIEW....................................6

PROCEDURES..13

RESULTS...19

DISCUSSION..20

RECOMMENDATIONS.....................................22

REFERENCE LIST......................................24

APPENDIX 30

INTRODUCTION

In 1969 the Philadelphia Fire Department began to convert its fleet of fire trucks from gas to diesel power. The first pumpers were particularly noisome. If permitted to run inside the station, these earliest diesels filled the garage (apparatus) floor as well as interconnected areas of the fire station with plumes of dark smoke.

In 1969 many of the fire stations in use pre-dated the completely motorized Philadelphia Fire Department. The older stations did not have a compartmentalized apparatus floor and none of the stations used diesel emission control systems. Because of their temperature, and the force at which they are expelled from the diesel engine, these fumes rise in the atmosphere and inside a building, easily travel beyond the immediate area of production. There are thousands of chemical compounds in these emissions, some of which are respiratory irritants, toxic or carcinogenic. Firefighters exposed to diesel emissions in the fire station may be at increased risks of lung cancer, bladder cancer and leukemia.

In this study, we examined the mortality risk for major causes of death among Philadelphia firefighters who were exposed to diesel emissions. For this purpose, we calculated the estimates of rate ratios (RRs) for major causes of death including cancer in the diesel exposed group relative to the non-exposed group. For lifetime diesel exposure, four exposure groups were defined: a)unexposed; b)low (1-259 diesel exposed runs); c) medium (259-1423 diesel exposed runs; c) high (>1423 diesel exposed runs).

These data are part of a larger study of firefighter occupational risk begun in Philadelphia during 1986 that we hope to publish later this year. Shelia H. Zahm, Sc.D., Senior Research Fellow, Occupational Studies Branch of the National Cancer Institute, granted me permission to use these data to conduct this analysis of diesel exposed firefighter cancer mortality risk for the Executive Fire Officer Program. Dalsu Baris, M.D.,Ph.D., Epidemiologist at the National Cancer Institute, produced the comparison of Risk Ratio’s presented in Table III. This research would not be possible without the expertise, hard work and dedication of the researchers at the National Cancer Institute, specifically Dr. Zahm, Dr. Baris and Ellen Heineman,Ph.D. Joel L. Telles,Ph.D., Vice-president of the Delaware Valley Hospital Council, worked with me in Philadelphia from 1984-1994. His assistance, especially his expertise in database design, was invaluable.

BACKGROUND AND SIGNIFICANCE

Fire departments throughout the country utilize diesel engines to power their fire trucks. Today the fleet of fire trucks used in the Philadelphia Fire Department (PFD) is exclusively diesel powered. This was not always the case. It was not until the arrival of the steam fire engine in 1858 that horses were accepted as a replacement for manpower. On December 31st, 1927 the last four fire horses made their final run, ending the non-motorized era of the PFD (Richman, 1971).

For the next forty-two years, gasoline internal combustion engines powered Philadelphia’s fire trucks. It wasn’t until 1969 that the PFD began to convert its gas powered trucks to the more economical diesel engines (Robrecht, 1992)

With the conversion diesel engines, the department did not abandon the older fire station. Although after World War II many fire station were renovated and constructed, older fire stations were still in use when the first diesel trucks arrived on the scene in 1969. These older stations were typically two or three stories with the apparatus floor, watch desk and kitchen area on the first floor; and, offices, bunkroom, bathroom and dayroom(s) on the upper floor(s). Stairs and poles connected the upper floors to the apparatus floor and these openings permitted diesel emissions to migrate throughout the station. Post-W.W.II stations were almost all one story and offered varying degrees of apparatus floor compartmentation (Garrity, 1990).

Although there is no quantitative substantiation, there are anecdotal reports that the first diesel pumpers used by the PFD produced notoriously dirty exhaust. Firefighters report the first diesel pumpers emitted dark plumes of smoke, especially when the engine was started cold. In at least one older station, firefighters parked the diesel pumper beside the open stairs to the second floor. The pumpers vertical exhaust stack pointed up the stairs and diesel exhaust traveled throughout the second floor offices and living areas.

Diesel emission particulates (soot) are carbonaceous clusters or chains that are sufficiently small as to be easily ingested or inhaled (Bernans,Shields,& McArthur 1983). Thousands of chemical compounds comprise the gas fraction of diesel emissions. Weisenberger (as cited by the National Institute of Occupational Safety and Health [NIOSH], 1992) describes how these chemicals, some toxic and others carcinogenic, can be adsorbed onto the diesel exhaust particle. In turn, individuals exposed to either the gas or particulate may ingest or inhale carcinogenic products of combustion (Bernans et al, 1983).

Exposure to diesel emissions in fire stations may increase the risk of occupationally induced cancer and other diseases for firefighters. If diesel emission exposure causes firefighters to become sick, this may in turn cause an economic burden to the fire service and the community we serve, specifically in terms of increased use of medical sick leave, increased firefighter medical insurance cost due to increased utilization and potential Workmen's Compansation liability.

The City of Philadelphia is self insured for Workmen's Compensation. If Philadelphia firefighters are routinely exposed to diesel emissions containing carcinogenic chemicals in the fire station, individuals who develop cancer will file Workmen's Compensation lawsuits and in all likelyhood win their lawsuits. The cost ultimately is borne by the taxpayer.

Fire Service executives have a responsibility to provide a safe fire station work environment for our employees, and reduce the potential liability for the community. Typically we are the public servants who enforce public safety laws and codes in our community. Reducing firefighter exposure to dangerous substances, whenever possible, protects our employees and the citizens we serve.

If there is an association between firefighter diesel emission exposure and increased cancer mortality risk, we can use this information to; 1) increase the existing body of information on firefighter occupational risk; 2) inform firefighters of the risk so they might take appropriate medical precautions; and, 3) use this information to convince the City Executives to fund the technology needed to reduce exposure, thus reducing danger and liability.

LITERATURE REVIEW

Firefighter Exposure

Increased cancer mortality risk from occupational exposure to products of combustion is nothing new. Young chimney sweeps in England suffered from unusually high rates of testicular cancer due to exposure from chimney soot (Landrigan, Golden & Markowitz, undated). Firefighters are exposed to toxic and carcinogenic products of combustion at structural fires when natural and synthetic materials oxidize. Several epidemiological studies suggest firefighters, as a result of their occupation, have an increased cancer risk as a result of such occupational exposure (Landrigan et al). At least two states acknowledge this cancer risk with presumptive workmen’s compensation cancer laws for firefighters (International Association of Firefighters [IAFF], undated).

In addition to fireground exposure to toxic products of combustion, firefighters face exposure to dangerous products of combustion in the fire station. According to Weixeldorfer (1992), when a diesel fire truck is started inside a fire station significant levels of diesel emissions are produced. Philadelphia firefighters usually start diesel apparatus at the start of each shift and of course each time they respond to a fire or medical emergency. When returning from the emergency the truck’s engine runs as it is backed into the station. If diesel emission control systems are not in place, then each time the truck engine runs inside the station, diesel fumes are produced and released inside that fire station.

A study of New York, Boston and Los Angeles fire stations using diesel trucks documented the dramatic rise in total air-borne particulates inside the fire station when a diesel engine runs. The study also reported a subsequent decline in airborne particulates, 35-40 minutes after the engine is shut down. In this study the researchers sampled the air inside ten fire stations. They concluded that the major contributor to air-borne particulates inside those ten stations was diesel emissions (Froines, Hines, Duffy, Lafuente & Liu, 1987). In a 1992 study of Lancaster, Ohio fire stations, NIOSH reached similar conclusions.

Studies confirm anecdotal reports of in-station diesel emission migration. NIOSH (1992) along with Weixildorfer (1992) report that diesel emissions, produced by trucks running in the fire station garage area, easily move through openings in floor and walls into the other areas of the station.

The level of exposure varies depending upon factor such as station design, diesel emission control systems and the number of vehicles operating. In busy East Coast fire stations (12 runs per day) researchers measured an average 300 micro-grams per cubic meter (ug/m^3) of particulates in the air. Of these 300 ug/m^3 of particulate the researchers believe, on average, 225 ug/m^3 of particulates and 54 ug/m^3 of methylene chloride extractable material captured were produced by diesel emissions. For comparison, the same researchers measured between 30-120 ug/m^3 of particulates outside the fire stations in New York and Boston (Froines et al, 1992).

In addition to fire station exposure to diesel fumes, firefighters operating diesel powered apparatus and equipment with ground level exhaust in the open air can be exposed to emissions(Pfeiffer, 1992). Fire training facilities may use diesel fuel to train firefighters in fire extinguishment. When the fuel burns it produces carcinogenic products of combustion. Instructors and firefighters in training may be exposed to these carcinogens (Atlas, Donnelly, Giam, & McFarland, 1985).

On the East Coast during the colder months the number of responses appears to have a direct effect on the level of diesel emissions in fire stations. Sampling of New York and Boston fire stations took place in March and April when the weather was cold with the windows and doors closed. According to the researchers, “there was an observable trend in the levels of diesel particulates as a function of runs. In general, the measured concentrations of diesel particulates increased with the number of runs/shifts. In the Los Angeles fire stations...there was no observable relationship between the number of runs and measured total particulates” (Froines et al, p.205).

Diesel Emission Composition

Diesel emissions consist of both gas and particulate. The gases are primarily carbon monoxide, nitric oxide, nitrogen dioxide, sulfur dioxide and hydrocarbons such as ethylene, formaldehyde, methane, benzene, benzo(a)pyrene, phenol, 1.3-butadiene, polynuclear aromatic hydrocarbons (PAH) and acrolein (Bernans et al, 1983; Holliday, Sifton, Englehardt, Langdon & Meng, 1981; NIOSH, 1992; Peters,1992) Diesel exhausts contain a multitude of chemical components with estimates varying from 9,000 to 18,000 chemical substances that might be adsorbed onto the carbon particulate. The particulates are small and can easily be inhaled or ingested(Bernans et al.; Peters). Gaseous chemical will coat the particulate, and these chemicals clinging to the carbon core may comprise 15%-65% of the total mass of this tiny particle (New Jersey Department of Health, 1986).

Carcinogens in Diesel Emissions

Several of the chemicals found in diesel emissions are known or suspected carcinogens. The International Agency for Research on Cancer (IARC) states that benzene causes acute myeloid leukemia in humans and is associated with causing lyphocytic leukemia (as cited in Linnet and Cartwright, 1990; American Cancer Society, 1997; Malone, Koepsell, Daling, Weiss, Morris, Taylor, Swanson, & Lyon, 1989).

IARC concludes that PAH causes skin and lung cancer and is associated with the pathogenesis of bladder cancer (as cited in Clavel, Mandereau, Limasset, Hemon & Cordier, 1994). Benzo(a)pyrene is an organic compound found on diesel particulates and belongs to the same chemical as benzene and PAH. Benzo(a)pyrene is especially problematic in that it is not only carcinogenic, but interferes with the production of lung collagen, a protein that regulates lung cell development and growth (Bernans et al, 1983).

Epidemiological Studies

A series of occupational studies this century such as Delore and Borgomo in 1928, Goguel, Cacigneux and Bernard in 1967 and Viglani and Forni in 1976 pinpointed spatio-temporal clusters of acute leukemia occurring in benzene-exposed shoe, leather, rubber, and rotoprinting workers in Italy, France and Turkey. Maternal occupational exposure to benzene is implicated with childhood acute myeloid leukemia (Laval & Tuyns, 1988; Shu, Gao & Brinton, 1988 as cited in Linet & Cartwright, 1990).

In a population-based case-control study of 427 cases of chronic lymphocytic leukemia, Malone et al. (1989) reports only a weak association with exposure to aromatic hydrocarbons. Aromatic hydrocarbons are a classification of chemical compounds that includes the BTX fraction: benzene, toluene and xylene. The author acknowledges the imprecise measurement of exposure in this study, which asked leukemia patients to estimate their own exposure level.

A case control study of the association of PAH and bladder cancer found a relative risk of 2 associated with jobs involving PAH exposure (Bonassi, Pearce, Puntoni, 1989). The results of a 1994 French study supports the causal relationship between occupational exposure to PAH and bladder cancer risk (Clavel et al, 1994).

In a study of occupational risk factors and bladder cancer in Canada, two occupations (motor vehicle driver and textile dyers) and one industry (motor transport) were found to have excessive risk to bladder cancer. However, this same study found only a slightly elevated risk of bladder cancer for occupational subsets of motor vehicle drivers exposed to diesel exhausts (Siemiatyci, Dewar, Nadon & Gerin, 1994).

In a case-control study of Teamsters, the researchers observed elevated lung cancer risks for long haul diesel truck drivers positively associated with duration of employment. The study found only a marginally elevated risk of lung cancer for diesel mechanics and slight deficit in risk for dockworkers. Short-haul diesel drivers, but not gasoline drivers, showed some evidence of increased risk. (Steenland, Silverman & Hornung, 1990).

Without naming specific etiologic agents, a study of leukemia incidence in the Portland-Vancouver metropolitan area found significantly elevated lymphathic and nonlymphatic leukemia rates among a number of blue-collar and white-collar jobs including firemen (Morton & Marjanovic, 1984).

In 1988, NIOSH published Current Intelligence Bulletin

50 titled Carcinogenic Effects of Exposure to Diesel Emissions. This NIOSH report concluded:

> Recent animal studies in rats and mice confirm an association between the induction of cancer and exposure to whole diesel exhausts. The lung is the primary site identified with carcinogenic or tumorigenic responses following inhalation exposures. Limited epidemiological evidence suggests an association between occupational exposure to diesel emissions and lung cancer. The consistency of these toxicological and epidemiological findings suggests that a potential occupational carcinogenic hazard exists in human exposure to diesel exhaust
>
> Tumor induction is associated with diesel exhaust particulates. Limited evidence indicates that the gaseous fraction of diesel exhaust may be carcinogenic as well.(p.25)

In a meta-analysis of 23 cohort and case-control studies of diesel exhaust exposure and lung cancer, the authors conclude that the data support a causal relationship between exposure to diesel emissions and lung cancer (Bahita, Lopipero, Smith, 1998).

Debra Silverman (1998) suggests that science has probably not proven causality for diesel emissions exposure and lung cancer in humans. She provides a strong arguement to conduct additional research, “Measuring the impact of diesel exhaust is important, not only to the 1.4 million workers expsoed to diesel exhaust, but also to the general population. Exposure to diesel exhaust is ubiquitous in U.S. cities, and those who commute on highways may experience substantial exposure" (p.5).

Firefighters are exposed to diesel emissions on the road, at emergency scenes, and in the fire station. In addition they are exposed to toxic and carcinogenic products of combustion at fires. The literature convinces me that firefighters are at risk, and that additional research is important, especially research that provides semi-quantitative exposure data, as attempted in this study.

PROCEDURES

Firefighter Work Histories

The PFD maintains work records of firefighters dating back to the turn of the century. These individual work histories are contained on an Employee Service Record (ESR) card about the size of a 5"x 7" index card. The cards are stored in the Personnel Office of the PFD. The cards contain identifying information such as name, address, badge number, phone number, Social Security number, as well as the dates of all career fire company assignments, commendations and disciplinary information.

The PFD granted permission to photocopy the ESR cards with the caveat that disciplinary information would be masked. We copied over 8,000 ESR cards, using a systematic quality check procedure (1:5 then 1:10 cards) to insure the photocopies were correct. We then delivered the records to the National Cancer Institute for data entry.

Because the PFD Personnel Office used codes on the ESR cards, we constructed a directory of those terms and codes. In the directory we described the elements on each card and provided a complete set of terms and appropriate abbreviations for the data entry staff.

Data entry teams identified approximately 950 ESR cards with missing or incomplete information, including 50 cards with all or some part of the name missing. By using records at the Fire Academy, Fire Museum, Union hall and PFD we resolved over 90% of the problems including the identification of 49 of the 50 cards with missing names.

The data entry teams, working under the guidance of the epidemiologist at the National Cancer Institute, compiled a database of over 54,000 work assignments for Philadelphia firefighters. With these data we know the number, type (engine, ladder), position, and duration of each career assignment for each Philadelphia firefighter in this cohort. We will use this database as the framework to construct a more complete work history. To this framework we added the type of a apparatus (diesel or gas) and the average number of responses at each assignment for each firefighter that worked between 1935-1986.

Apparatus

Mr. Jack Robrecht, former curator of Firemen's Hall (Fire Museum), maintained a log of every fire apparatus assignment in the PFD from 1871-1986. Mr.Robrecht provided us with a copy of the log and we created a database of fire apparatus assignments. Using this information we know the type of apparatus (non-motorized, gasoline, or diesel) assigned to each Philadelphia fire company from 1871-1986. With these data we attached to each firefighter's work history the type of motorized apparatus, diesel or gas, for each career assignment. These data permit us to compare mortality risk between two groups: diesel exposed and non-diesel exposed firefighters.

Fire Company Activity

In order to estimate fire station exposure for the diesel-exposed group, we collected information on fire company activity. If diesel emissions levels inside the fire station increase by the number of runs/shift, as suggested by Froines et al. (1987), then the number of career runs a firefighter made at assignments using diesel apparatus would be a crude estimate of diesel emissions exposure, relative to the cohort.

By searching through records at the PFD, the Fire Museum, and the Union we assembled considerable information on annual fire company responses. Then we entered the information into a spreadsheet (Runs file), and sent the information to the National Cancer Institute. The Runs file provided the annual number of fire company responses (runs) for each fire company for each year, 1935-1986.

NCI adjusted the data by the number of working platoons each year, then attached to each firefighters work history, the average number of runs the firefighter made at each career fire company assignment. This information permits us to total an firefighter's career runs with diesel apparatus. This cumulative number of diesel responses provides a crude estimate of a firefighters exposure to diesel emissions in the fire station. Using this estimate we compared mortality risks of Philadelphia firefighters with different relative diesel emission exposure.

VITAL STATUS

In order to compare mortality rates of diesel-exposed and non-exposed firefighters we had to first determine the vital status of the cohort i.e. who is still living and who is deceased. This was done in several steps.

We initially separated active firefighter ESR cards from retired, and the Board of Pensions provided a list of retired firefighters still receiving pensions. These two groups, active firefighters and retired firefighters receiving pensions were known to be living.

The Board of Pension granted permission to access pension records. If the family of a deceased firefighter (spouse or dependent children) receives a pension check, a copy of the deceased firefighter’s death certificate is in a file at the Board of Pensions. Searching pension files and Local 22 Firefighters files we obtained over 2,000 copies of death certificates.

Using these copies the National Cancer Institute (NCI) obtained approximately 1800 original death certificates from State Bureaus of Vital Records. With access to B.I.R.L. (the Department of Defense Veteran’s Affairs Beneficiary Information Record Center), the National Death Index, Equifax, the Union archives, the PA Department of Transportation and the Philadelphia Police and Fire Medical Association researchers at NCI and in Philadelphia determined the vital status of 89% of the total cohort and 96% of the firefighters who worked for the PFD between 1930-1986. Overall 1,196 persons were lost to follow-up. Table 1 shows the success of the tracing.

Table I: Tracing of Philadelphia Firefighters.

Year Hired	Cohort Size	% Successfully Traced
1880 + (Total)	8,501	89
1910 +	8,130	91
1920 +	6,860	95

1930 +	4,908	96

(Zahm, 1994)

Methods

To test the hypothesis that firefighters exposed to diesel emissions in the fire station have an increased risk of cancer, we included 6,477 firefighters who were hired between 01/01/1936 and 12/31/85 in our analysis. We considered lifetime diesel exposure as a risk factor, and for each firefighter, we calculated person-years in each of the exposure category stratified across age and calendar years. Diesel exposure was treated as a time dependent variable. This means that firefighters moved from one exposure category to another over their follow-up period instead of being assigned to a fixed category of exposure. This allowed firefighters to contribute their person-year experience at different ages and calendar years progressively through ordered categories of exposure. The exposure categories are in Table II.

Table II. Exposure Categories.

	Zero Exposed	Low Exposed	Medium Exposed	High Exposed
Diesel Runs	0	1-259	259-1423	>1,423
FF Deaths	836	126	130	130

We calculated rate ratios (RRs), and 95 % confidence intervals (CI) for each major cause of death. The RRs (also referred to as a risk ratio or relative risk) permits a comparison of risk in the exposed categories relative to the unexposed.

RESULTS

Table III (Appendix), prepared by Dr.Baris, lists the RRs for each major cause of death by exposure category. In each column below the "O" is the number of observed deaths for each cause. The number in parenthesis beside each RR is the 95% Confidence Interval(CI). The CI informs us of the reliablity of the RR.

There was no evidence of increased overall mortality and all cancers combined among Philadelphia firefighters. The RR for all causes of death and for all cancer were either below one or close to one in all exposure categories. There appears to be an increase in risk for the medium exposed group, when compared to the low-exposed group, for leukemia, malignant neoplasms of brain and nervous system. There are elevated risks for prostate cancer in all three exposed groups. Although the RRs were elevated for these causes, the results were not statistically significant. Having very small number of observed specific cancer deaths in the exposed categories resulted in unstable RRs with wide confidence intervals. This made it very difficult to reach any meaningful conclusion whether diesel emissions associated with any excess mortality for a specific cancer site.

DISCUSSION

Our results showed no evidence of increased overall mortality. The RR for all causes of death and for all cancer were either below one or close to one in all exposure categories. This study may very well be the first attempt to estimate career cumulative exposure levels for diesel emissions for a large cohort of urban firefighters. This may also be the first attempt to evaluate the risks to diesel emissions exposure for firefighters. As with any first attempt there are unforeseen problems.

Other studies of occupational groups exposed to diesel emisssions have found elevated cancer risk. In a study using data from the American Cancer Society, truck driver with long-duration exposure to diesel emissions had an elevated risk of lung cancer. The same study found that exposure to diesel emissions produced increased lung cancer risk, regardless of the occupation (Boffeta, Stellman, Garfinkle, 1988).

Steenland (1990) suggested that teamsters with long-term employment as long-haul truckers after 1959 had an increased risk of lung cancer that increased with duration of employment. Two other case-control studies have implicated diesel exposure with increased cancer risk (Jensen, Wahrendorf, Knudson, & Sorenson, 1987; Silverman, Hoover, Mason, & Swanson, 1986).

When we compare Steenland's study to this study, several shortcomings in our study are obvious. First there is the short period of diesel exposure for firefighters. Diesel trucks were introduced into the PFD in 1969. In the trucking industry diesels were introduced in the 1950's and 1960's. This occurred even earlier in the Western United States. By 1961 diesel trucks outnumbered gasoline powered heavy trucks in new truck sales (Motor Vehicle Manufacturers Association, 1992 as cited in Steenland et al., 1990). Teamsters had a longer opportunity for exposure. Steenland et al. found that both long-haul and short-haul diesel truck drivers showed increased cancer risk with increased years of exposure. Longer exposure for Philadelphia firefighters may mean an increased cancer risk.

Other limitations of our study are the small number of observed deaths and the short period (17 years) since first exposed. This may be too short of a latency period for the cancers associated with diesel exposure to influence mortality rates.

Other factors such as fire station design will effect firefighter exposure to fire station diesel emissions. There are at least three distinctly different types of fire station designs in Philadelphia. Exposure levels will vary at different stations. We've already added information on station design categories to the database. We can utilize these additional data to refine and improve exposure estimates for future analysis.

RECOMMENDATIONS

Our results did not show any excess in overall mortality associated with diesel exposure. The results of for specific cancer risk from diesel exposure are inconclusive because of the small study size and lack of statistical power. These data do not permit us to conclude that firefighters face an elevated cancer risk due to diesel emissions, and perhaps even more importantly, they do not support a conclusion that Philadelphia firefighters are not at risk. Larger studies and studies with longer follow-up periods are required to obtain meaningful results.

The literature review was conclusive. Diesel emissions contain toxic and carcinogenic products of combustion. Carcinogens such as benzene, found in diesel emissions, have a long history of causing occupational cancer. There are no acceptable personnel exposure levels for carcinogens. If we look at the body of research on animal and human exposure to diesel emissions, it is logical to conclude that long term exposure to diesel emissions is likely to result in a carcinogenic effect.

The Fire Service is not likely to abandon the diesel engine in the near future. The newest ladders placed in service this week in Philadelphia are all diesel powered. In NFPA 1500, the National Fire Protection Association directs fire service managers to exhaust diesel emissions from fire stations. The technologies existing today permit us to all but eliminate diesel emissions from the fire station. The American Fire Service should use this technology to end firefighter exposure to diesel emissions.

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APPENDIX

TABLE III : Rate Ratios (RR) and 95 % CIs for Major Causes of Death Among Philadelphia Firefighters: 1935-1986 by Number of Lifetime Runs with Diesel Exposure (N=6,477)

	Non-exposed (Zero exposed runs)		Low 1-259 exposed runs		Medium 259-1423 exposed runs		High >=1423 exposed runs	
Cause of Death	O	RR	O	RR (95% CI)	O	RR (95% CI)	O	RR (95% CI)
All causes (001-999)	836	1	126	0.86 (0.71-1.04)	130	0.74 (0.61-1.04)	130	0.68 (0.54-0.85)
Malign neoplasms (140-209)	217	1	37	1.02 (0.72-1.44)	43	0.99 (0.70-1.39)	31	0.74 (0.48-1.14)
Buccal cavity and pharynx (140-149)	3	1	2	3.51 (0.58-21.35)	3	3.31 (0.61-17.87)		- -
Esophagus (150)	2	1	1	2.70 (0.24-30.34)	. 1	1.74 (0.15-20.79)	2	3.43 (0.35-34.14)
Stomach (151)	5	1	2	2.33 (0.43-12.67)		- -	-	
Large intestine (153)	36	1	5	0.79 (0.31-2.03)		0.24 (0.06-1.00)	4	0.44 (0.14-1.43)
Rectum (154)-	3	1	2	3.72 (0.61-22.58)		1.33 (0.13-013.74)		- -
Liver (155-156)	4	1	-	- -	-	- -		- --
Pancreas (157)	13	1	3	1.31 (0.37-4.64)	1	0.36 (0.04-2.88)		0.76 (0.13-4.36)
Larynx (161)	3	1	-	- -	-	- -		-
Lung (162)	70	1	10	0.84 (0.44-1.64)	17	1.26 (0.73-2.19)	12	1.13 (0.56-2.26)
Cancer of skin (172-173)	5	1		- -	1	0.55 (0.05-5.62)	1	0.15 (0.00-2.26)
Prostate (185)	9	1	5	2.66 (0.82-8.62)	3	2.32 (0.62-8.76)	2	3.13 (0.62-15.88)
Bladder (188)	5	1	1	1.34 (0.16-11.70)	-	- -		- -
Kidney (189)	7		1	0.78 (0.09-6.40)	-	- -	1	0.53 (0.51-5.48)
Brain and nervous system (191-192)	3		1	1.80 (0.19-17.50)	3	4.58 (0.79-26.40)	-	
Non-Hodgkin's lymphoma (200, 202)	13				3	1.05 (0.25-4.41)	1	0.24 (0.02-7.98)
Multiple Myeloma (203)	3	1			2	5.28 (0.73-38-42)	1	2.78 (0.16-47.83)
Leukemia (204-207)	7	1		0.94 (0.12-7.72)	3	2.49 (0.55-11.29)	2	1.63 (0.21-12.77)
Benign neoplasms (210-230)	7	1		- -	1	0.51 (0.05-4.92)		0.44 (0.03-6.32)
Allergic, endocrine & nutritional diseases (240-279)	12	1	3	1.48 (0.41-5.32)	1	0.38 (0.05-3.13)		0.23 (0.02-2.61)
Nervous system diseases (320-389)	7	1	2	1.88 (0.38-9.23)	-	- -		
Circulatory diseases (390-458)	427	1	55	0.76 (0.60-1.00)	43	0.53 (0.39-0.74)	47	0.63 (0.44-0.89)
Atherosclerotic heart diseases (410-414)	312	1	40	0.75 (0.54-1.04)	30	0.51 (0.35 -0.75)	37	0.69 (0.46-1.02)
Vascular diseases of CNS (430-438)	47	1	3	0.38 (0.12-1.22)	3	0.33 (0.10-1.09)	4	0.45 (0.14-1.50)
Respiratory diseases (460- 519)	27	1	6	1.32 (0.55-3.20)	7	1.45 (0.61-3.43)	6	1.46 (0.52-4.13)
Emphysema (492)	2	1	2	6.05 (0.85-43.24)		- -		
Digestive system diseases (520-577)	52	1	5	0.56 (0.22-1.40)	11	0.98 (0.50-1.97)	6	0.45 (0.16-1.24)
Gastric and duodenal ulcers (531 -553)	4	1	1	1.49 (0.17-13.36)		1.96 (0.19-20.31)		
Cirrhosis of liver (571)	35	1	2	0.31 (0.07-1.29)	8	0.82 (0.36-1.89)		0.21 (0.05-0.82)
Genitourinary disease (580- 629)	8	1	1	0.84 (0.10-6.86)	1	1.10 (0.13-9.04)		
All external causes of death (E800-E998)	59	1	8	0.80 (0.38-1.70)	11	0.55 (0.26-1.13)	27	0.53 (0.26-1.08)
All accidents (E800-E949)	38	1	4	0.72 (0.26-2.06)	7	0.80 (0.32-2.01)	19	1.04 (0.42-2.57)
Suicide (E950-E959)	17	1	4	1.03 (0.34-3.14)		0.08 (0.01-0.70)	4	0.10 (0.02-0.42)